LOCAL GOVERNMENT BOARD.

MEDICAL DEPARTMENT.

MEMORANDUM

ON

CERTAIN METHODS IN USE FOR THE STERILIZATION OF THE EXIT AIR FROM THE WARDS OF SMALL-POX HOSPITALS.

PREPARED BY

Dr. F. W. BARRY.

October 1893.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
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Memorandum, prepared by Dr. F. W. Barry for the Local Government Board, on Certain Methods in use for the Sterilization of the Exit Air from the Wards of Small-pox Hospitals.

In the following Memorandum I propose to give a brief account of some recent attempts that have been made by Local Authorities to obviate the spread of infection from small-pox hospitals to surrounding populations.

Separate attempt has been made in this direction by the Sanitary Authorities of Barnsley, Nottingham, and Bradford. In each instance the objects aimed at have been the withdrawal of the air from the small-pox wards along certain definite channels, and the subsequent sterilization of this air by heat, in accordance with the suggestions made by Professor Burdon Sanderson in his evidence before the Royal Commission respecting Small-pox and Fever Hospitals in 1882.

To the Barnsley Urban Sanitary Authority is due the credit of being the first authority to attempt the experiment; the small-pox pavilion erected in connexion with the Kendray Hospital at Barnsley in 1889 having been designed to carry out Professor Sanderson's suggestions. The Nottingham Urban Sanitary Authority adopted similar principles in the erection of a small-pox block at the Bagthorpe Hospital which was completed in 1890. At Bradford the new small-pox wards built in connexion with the Corporation's Hospital for Infectious Diseases were completed in 1891.

In the following account I propose to give, with regard to each of these small-pox pavilions—

(*a.*) A general description of the buildings;
(*b.*) A detailed account of the special arrangements made for securing the withdrawal of the exit air along definite channels, and for the subsequent sterilization of this air; and
(*c.*) Notes as to experiments made for testing the efficiency of the special arrangements at each hospital.

1. Kendray Hospital, Barnsley, Small-pox Pavilion.

(*a.*) *General Description.*—This small-pox pavilion, which was completed in 1889, was erected from designs made by Messrs. Morley and Woodhouse, of Bradford, and to these gentlemen I am indebted for the annexed plans A—H.

These plans comprise :—

A. Elevation of small-pox pavilion.
B. Ground plan ,, ,,
C. Basement plan ,, ,,
D. Longitudinal section of small-pox pavilion.
E. Transverse ,, ,, wards.
F. Section showing sterilizing arrangements for ward.
G. Section showing separate sterilizing arrangements for waterclosets and bath-rooms.
H. Plan showing position of gas furnaces and air ducts in vitiated air chamber.

The pavilion, as will be seen from plans A and B, consists of two parts, one containing kitchen, scullery, and store-rooms, and the other the wards proper. The second portion of the establishment only is within the sphere of the sterilizing apparatus.

These two buildings communicate with one another by means of a glazed corridor provided with moveable sashes so as to allow of the two buildings being disconnected.

The ward block proper is circular in form, with two projections, one communicating with the corridor and containing nurses' duty rooms, and the other on the opposite side of the block containing water and slop closets.

The circular portion of the building is divided into two chambers by means of a circular wall erected at a distance of 18 feet from the outer wall. The outer annular space forms the ward, and is divided into two equal parts for male and for female patients respectively. The inner chamber, which has a diameter of 20 feet 6 inches, and which is furnished with a central chimney, contains in the basement the furnace in connexion with the apparatus for warming the wards (see Plan C), and upon an upper floor the apparatus for sterilizing the exit air (see Plans D, E, and F).

The wards themselves (after deducting the space occupied by a bath room) have each a superficial area of 1,082 square feet and an air space of 11,900 cubic feet, and are designed to accommodate five beds, thus allowing a floor space of 216 square feet and an air space of 2,380 cubic feet per patient. Each ward is lighted by means of seven windows. The warming of the wards is effected by means of hot water pipes arranged along the outer wall, and in addition there are three coils in each ward.

(*b.*) *Ventilation and Sterilization Arrangements.*—As regards the ventilation of the wards, the following arrangements have been made; four openings are situated in the outer wall of each ward at the floor level, and consist of gratings 13½ inches long by 8½ inches wide. Of this space about one half is available. There are in addition three other openings in the outer wall, provided with gratings, each 20½ inches by 3¾ inches in size, of which space about one-third is available. These latter openings communicate directly with the hot water coils already referred to, and are intended to act as inlets in cold weather. These several sets of openings are shewn in Plan C. In addition to these openings, the upper sash (27 by 49 inches) of four of the seven windows in each ward can be opened by means of a quadrant. All the openings above noted are intended to act as inlets, and arrangements are made whereby the gratings can be opened or closed at will. The outlet ventilators are all situate in the inner circular wall (see Plans D and E). Of these there are in the block 17 openings, each 8 inches in diameter, situate close to the ceiling and each communicating directly with a Keeling's Sewer Gas Destructor, Plan F, where the exit air is subjected to the flame of a gas Argand burner. The air thus treated is carried by means of earthenware tubes into the central chimney. Plan H shows these arrangements. A separate gas destructor communicating with a separate shaft has been provided to draw off and sterilize the air of the water and slop closets (see Plan G).

(*c.*) *Efficiency of the Apparatus.*—In testing the efficiency of the ventilating and sterilizing arrangements of this hospital, I had the advantage of the assistance of Dr. Whitelegge, Medical Officer to the West Riding County Council, and of Dr. Theodore Thomson, at that time Medical Officer of Health for Sheffield. Dr. Sadler, the Medical Officer of Health for the Borough of Barnsley, was also present during portions of each day. On the occasions when the experiments were made, the apparatus for warming the wards and the apparatus for sterilizing the air had in each case been in action for some 12 hours prior to the time of our visit. The experiments were conducted in the male ward. First of all we endeavoured to ascertain whether the extractive power provided was sufficient to prevent the escape of air from the ward through any openings other than those specially provided for this purpose. We at once found that it did not in this sense suffice. *First,* as regards the door communicating between the ward and the corridor, it was ascertained that when the door was slightly opened the draught inward through it was almost nil, with occasional gusts *out* from the ward, and that the result attained was practically the same whether the air inlets in the outer wall were open or shut. But when the door was opened widely there was a strong current of air *out* from the ward. The temperature of the ward and of the outer air was on this occasion 62° and 45° Fahr. respectively. *Secondly,* as regards the seven air inlets in the outer wall:—

(*a.*) With all the doors and windows closed, and with four of these air inlets open, simultaneous readings of anemometers taken at Nos. 1, 2, and 4 inlets (Plan C) gave the following results during five minutes :—

No. 1.	No. 2.	No. 4.
276 feet in.	658 feet out.	1,090 feet in.
22 „ out.	2 „ in.	No oscillations.
339 „ in.	3 „ out.	
2 „ out.	4 „ in.	
2 „ in.	10 „ out.	
3 „ out.	10 „ in.	
608 „ in.	93 „ out.	
54 „ out.	5 „ in.	
2 „ in.	5 „ out.	
9 „ out.		
11 „ in.		
18 „ out.		
111 „ in.		
16 „ out.		
13 „ in.		
2 „ out.		
2 „ in.		
8 „ out.		
120 „ in.		

(*b.*) With the door between the corridor and the ward open, all windows closed, and the same four of the seven inlet gratings open, simultaneous readings of anemometers taken at Nos. 1, 2, and 4 inlets (Plan C) gave the following readings during five minutes :—

No. 1.	No. 2.	No. 4.
22 feet in.	1,788 feet out.	914 feet out.
194 „ out.	No oscillations.	No oscillations.
7 „ in.		
95 „ out.		
10 „ in.		
32 „ out.		
5 „ in.		
218 „ out.		
10 „ in.		
13 „ out.		
22 „ in.		
48 „ out.		
48 „ in.		
36 „ out.		
4 „ in.		
42 „ out.		
10 „ in.		
150 „ out.		

From the above observations it will be clear that the object aimed at was not attained; that the "inlets" as frequently acted as outlets as the reverse; and that the mere fact of opening the door at once caused openings, which under other circumstances acted as inlets, to be converted into outlets. It was in addition definitely ascertained that it was impossible to prevent oscillations of the air through the air inlets. As regards the air outlets immediately on the ward side of the gas jets, it was found that whilst they invariably acted as outlets, there was considerable variation in the amount of air passing through them. Taking the average, the amount of air passing through each outlet amounted to about 3,000 cubic feet per hour.

In order to test the sterilizing power of the gas jets in the air outlet flues two series of experiments were made; the wards not being in use at the time for the occupation of patients. In both series the same procedure was adopted. At a point (see Plan H (D)) immediately beyond the junction of the flues from three of the gas jets referred to, a hole was knocked in one of the flues (at this point horizontal) leading to the main exit shaft, and by this aperture were introduced Soykas glass capsules containing a thin layer of agar-gelatine. The method of preparation of these capsules and their contents had been

as follows,—Over the bottom of each of the capsules, previously sterilized, was run a thin layer of sterile agar-gelatine; the capsule was then closed and again sterilized. All the capsules were enclosed in sterilized linen bags, and thus conveyed to the Kendray Hospital. When a capsule was about to be used it was removed from its bag, and introduced within the flue above described, its lid being taken off at the instant of introduction and returned to the bag. It was then pushed forward along the interior of the horizontal flue for the distance of about a foot towards the gas jets, when it was turned on its edge so that the layer of contained agar-gelatine was vertical and faced the current of air coming past the gas jet along the pipe from the wards. The current of air thus impinged directly upon the agar-gelatine surface. After being allowed to remain in that position for a definite period the capsule was withdrawn, re-covered, and returned to the sterilized bag.

The first series of experiments for testing the sterilizing apparatus were conducted on May 28th, 1891. Previously however to exposing the capsules (four in number) in the flue as described above, three other capsules, (*a*), (*b*), and (*c*), were exposed on the floor of the ward itself (see Plan B), with the view of determining the condition of the air about to pass over the gas flames. They were allowed to stand uncovered during a period of 20 minutes. At the beginning of this period a door-mat had been violently shaken in the ward in the vicinity of capsule (*a*). The times of exposure were :—

(*a*) from 3.10 to 3.30 p.m.
(*b*) „ 3.12 to 3.33 p.m.
(*c*) „ 3.15 to 3.35 p.m.

The remaining four capsules (*d*), (*e*), (*f*), and (*g*) were an hour and a half later exposed in the particular flue leading from the ward to the main exit shaft already referred to, and in the manner described above.

The times of exposure were :—

(*d*) from 5.3 to 5.8 ; a period of 5 minutes.
(*e*) „ 5.10 „ 5.15 ; „ 5 „
(*f*) „ 5.25 „ 5.35 ; „ 10 „
(*g*) „ 5.45 „ 6.5 ; „ 20 „

From the date of exposure, May 28th, up to June 1st, all these capsules were kept in the laboratory at the room temperature. On June 1st they were examined, and it was found that capsule (*a*) contained over 120 colonies of moulds and bacteria; capsule (*b*) contained over 80 colonies; capsule (*c*) contained over 50 colonies. In the four other capsules, (*d*), (*e*), (*f*), and (*g*), no colonies were visible. These four were on this date transferred to the incubator and kept at a temperature of 37° C. until June 4th. During this time no colonies appeared, and observation of them was discontinued.

The second series of experiments for testing the sterilizing apparatus were conducted on June 3rd. Three capsules only were made use of. All these were exposed in the same flue leading from the ward to the main exit shaft in the manner already described. At the time that the first of these capsules (α) was being exposed, a door-mat was violently beaten in the ward near the three exit apertures through which air would pass to reach the flue in which the capsules were exposed. (α) was exposed for a period of one minute; (β), for a period of five minutes; and (γ), for fifteen minutes. (β) was exposed immediately after (α) was withdrawn, and (γ) immediately after (β) was withdrawn. From the date of exposure, June 3rd, up to 5.30 p.m., on June 5th, all three capsules were kept in the laboratory at the room temperature. At 5 p.m., on June 5th, over 80 colonies of moulds and bacteria were visible in (α); over 130 colonies in (β). In (γ) no colonies were observed. On this date at 5.30 p.m. the three capsules were transferred to the incubator and maintained at a temperature of 37° C. At 1 p.m. next day, June 6th, many of the colonies in (α) and (β) were found to have coalesced, so that it was impossible to count them with any approach to accuracy. In (γ) 16 colonies were observed. (γ) was replaced in the incubator and re-examined on June 8th, at 10.30 a.m., when 35 colonies of moulds and bacteria were observed. Observations were then discontinued.

As a control to both series of experiments capsules containing agar-gelatine prepared at the same time and in the same way as those used in the above experiments, were kept under the conditions applying to the latter after exposure. In no case did any colony appear in any of these.

2. Bagthorpe Hospital, Nottingham, Small-pox Pavilion.

(*a.*) *General Description.*—This small-pox pavilion which was completed in 1890 was erected from designs made by Mr. Arthur Brown, M.Inst.C.E., the Borough Engineer of Nottingham, to whom I am indebted for the annexed plans I—M. These plans comprise :—

I. Ground plan of small-pox pavilion.
K. Longitudinal section of small-pox pavilion.
L. Transverse section of small-pox pavilion.
M. First floor of administrative annex to small-pox pavilion.

From the ground plan I. it will be seen that the small-pox pavilion at the Bagthorpe Hospital consists of a ward block with an administrative annex separated from it by means of a cross ventilated corridor. The ward block proper contains two large wards, each 60 feet long by 25 feet broad, arranged on either side of a central ward kitchen and entrance lobby. At the two outer angles of each of the wards, and separated from them in each instance by means of cross-ventilated lobbies, are projections which contain (α) a bath-room and lavatory, and (β) water and slop closets respectively; whilst adjoining the outer angles of the ward kitchen are other two projections, each comprising a small ward for the isolation of a single patient. The large wards are each constructed to accommodate ten beds, each bed having a floor space of 150 square feet and an air space of upwards of 2,000 cubic feet.

(*b.*) *Ventilation and Sterilization Arrangements.*—Air is admitted to the wards (1) by means of windows at the distal end and on either side of the ward; (2) by "ventilating" fireplaces which draw in fresh air from the outside; and (3) by air inlets in the outer walls. The only special arrangement as regards ventilation made at this hospital has been the construction of horizontal "extraction" shafts above the ceiling of the wards and communicating with them by means of openings situate immediately over gas jets lighting the wards. These shafts, which are designed with the object of extracting the ward air, are carried to the centre of the building where they discharge into a vertical shaft surrounding the smoke flues from the ward fireplaces, the smoke flues themselves being carried up a central smoke tower (see Plans I, K). A large Bunsen gas burner placed in the vertical shaft referred to above, is the only means employed to sterilize the exit air from the wards.

(*c.*) *Efficiency of the Apparatus.*—In testing the efficiency of the ventilating and sterilizing arrangements at this hospital I had the assistance of Dr. Whitelegge, Medical Officer of Health to the West Riding County Council, formerly Medical Officer of Health for Nottingham, and of Dr. Boobbyer, the present Medical Officer of Health for Nottingham and Superintendent of the Bagthorpe Hospital.

Without entering into detailed description of the experiments, it will readily be understood from the brief description given of the ventilating arrangements that the windows and air inlets could not be depended upon to act as inlets only; they must needs have frequently acted as outlets. By means of a number of experiments it was ascertained that it was impossible to prevent this. As regards the extraction shaft also it was ascertained that whilst a considerable amount of air was apparently drawn through the openings in it nearest to the central shaft, the amount decreased in proportion to the distance of the openings from the central shaft.

The arrangements made to secure the sterilization of such air as passed through the extraction shaft were practically useless, as I found it possible to pass pieces of cotton wool and tissue paper up the shaft beyond the Bunsen gas burner without their being even singed. I was further given to understand that owing to the ease with which the gas flames of the Bunsen burner were extinguished by the draught in the smoke tower, their use had been practically discontinued.

3. Bradford Corporation Fever Hospital. Small-pox Block.

(*a.*) *General Description.*—The small-pox pavilion in connexion with the fever hospital of the Bradford Corporation, was erected in 1891–92, from designs made by Messrs. Morley and Woodhouse, of Bradford; the same architects who designed the small-pox pavilion in connexion with the Kendray Hospital, Barnsley, already referred to in this Memorandum. To these gentlemen I am indebted for Plans N—Q., which comprise—

N. Ground plan of small-pox pavilion.
O. Basement plan „ „
P. Longitudinal section of small-pox pavilion.
Q. Transverse section „ „

From Plan N it will be seen that the existing pavilion contains two wards, each 72 feet in length by 15 feet in width, which are placed back to back, but separated from one another by a central air chamber 3 feet in width. A projection at the distal end of each ward contains a bath-room, water-closet, slop-closet, and dirty linen shoot; whilst a nurses' room is provided at the entrance end of each ward furnished with a fixed window between it and the ward; and beyond the nurses' room, on one side of the entrance corridor, a separate private ward has been provided, whilst on the opposite side are situate rooms for the disinfection of convalescents before their discharge from the hospital.

The central air space between the wards is divided by means of horizontal partitions into three chambers one above another (see Plan Q); of these chambers the two lower are situate below the level of the floors of the wards, and comprise arrangements for passing air into the wards after warming it; whilst the upper chamber is intended for the withdrawal of vitiated air from the wards.

The two large wards are each designed to accommodate six beds, and each has a superficial area of 1,080 square feet and an air space of 11,880 cubic feet, thus allowing a floor space of 180 square feet and an air space of 1,980 cubic feet per patient. Each ward is lighted by means of seven windows.

(*b.*) *Ventilation and Sterilization Arrangements.*—The special arrangements made at this hospital for ventilating the wards and for sterilizing the air withdrawn from them are of an elaborate character. This work was carried out by Mr. Edwin Oldroyd, of Leeds, who has obtained a patent for the system in question.

All the windows are hermetically sealed and the fresh air is let in solely by means of three shafts communicating with the external air on the one side and with the lowest compartment of the 3-foot space between the wards on the other. (See Plans P (A) and Q.) Above this compartment and divided from it by flags with open joints is the second compartment, along which, for the purpose of warming the incoming air, a large number of low pressure hot-water pipes are fixed. (See Plans P and Q.) From this compartment flues are carried to six openings in the floor of each of the two wards; these openings are situate at the foot of each bed and covered by gratings. (See Plan Q.) Each bed-foot grating has a net available area of one and a half square feet. Further flues from this compartment are carried to three openings in each of the wards;* these openings, which each have a net available area of 73 square inches, are situate at the floor level in the wall of the ward opposite to the windows. There are thus nine air inlets provided in each ward having an aggregate available area of nine and a half square feet. Above the pipe chamber is situate the uppermost compartment or vitiated air chamber. Into this compartment openings are made at the ceiling level of the ward-wall over each bed. These openings vary slightly in size from 40 inches by 2 inches to 40 inches by $2\frac{5}{8}$ inches, but their average area is 96 square inches, or two-thirds of a foot, thus giving an aggregate area of 4 square feet for each ward. A powerful furnace, with honeycombed firebrick divisions, is placed in the cellar at the distal end of this chamber, and is designed to draw the air out of the wards. The furnace is so arranged that a considerable portion of the vitiated air is used to promote the combustion of the fire, the remaining portion being passed through the furnace and exposed to an estimated temperature of 800° Fahr., before being passed

* These openings are not shown on the plans.

out into the open air through the chimney. By this method it is considered that the exit air from the wards will be thoroughly sterilized before being discharged into the open air. The projections containing the waterclosets, bath-rooms, &c., are also directly connected with this "exhaust" system.

(*c*.) *Efficiency of the Apparatus*.—In testing the efficiency of the ventilating and sterilizing arrangements of this hospital I had the advantage of the assistance of Dr. Whitelegge, Medical Officer of Health to the West Riding County Council, of Dr. Evans, Medical Officer of Health for Bradford, of Mr. W. T. Morley, the architect, and of Mr. Edwin Oldroyd. The Chairman of the Sanitary Committee of the Corporation and the Medical Superintendent of the Fever Hospital were also present during a considerable portion of the experiments. On the occasion when the experiments were made, the apparatus for warming the wards and the apparatus for sterilizing the air had been put into action some 12 hours prior to the time of my visit. This had been done under the immediate superintendence of the architect and the engineer. The experiments were conducted in No. 1 ward which had not at the time been used for occupation by patients.

First of all, as at Barnsley, we endeavoured to ascertain whether the air inlets always acted as such, and we found that although there was considerable variation in the amount of air passing into the ward through the air inlets, under no circumstances did they act as outlets. With the doors closed and all the inlets open, simultaneous readings of anemometer taken at the six air inlets in the floor gave the following results during five minutes:—

No. 1 (next entrance)	-	344 feet in (current intermittent).
No. 2 - -	-	267 „ in.
No. 3 - -	-	400 „ in.
No. 4 - -	-	750 „ in.
No. 5 - -	-	325 „ in.
No. 6 (next lavatory)	-	329 „ in.

Under similar conditions readings of anemometers taken at the three inlets in the rear wall of the wards during five minutes, gave the following results:—

No. 1 - -	-	1,704 feet in.
No. 2 - -	-	640 „ in.
No. 3 - -	-	360 „ in.

The anemometer readings taken at the floor inlets gave an average of 403 feet in during five minutes, or after correction for anemometrical error, of 553 feet, or 6,636 feet per hour. This amount, calculated upon the net available area of the inlet openings, gives an air supply of 9,954 cubic feet per patient per hour.

In like manner the anemometrical readings taken at the wall inlets gave an average of 901 feet in five minutes, or a corrected reading of 1,051 feet, equivalent to 12,612 feet per hour. This amount, calculated upon the net available area (half a square foot) of each of the inlet openings, gives an air supply of 6,306 for each of the three air inlets, or 3,153 cubic feet per hour per patient. Adding together the amount of air passed through the two sets of air-inlets, the aggregate amount of air per patient at the time of experiment was upwards of 13,000 cubic feet per hour.

Upon testing the spaces below the doors leading from the waterclosets and from the corridor into the ward respectively, a further draught into the ward was found, which would add somewhat to the above amount. The temperature of the ward at the time of experiment was, dry bulb, 69° F., wet bulb, $59\frac{1}{2}$° F. The thermometer readings outside were: dry bulb, 45° F.; wet bulb, 44° F. The temperature of the air passing through the inlets was 72° F.

As regards the air outlets, simultaneous readings under similar conditions to those noted with respect to the air inlets, were taken with the following results during five minutes:—

			Ins. Ins.
No. 1.	1,436	feet out; area of outlet	$40 \times 2\frac{5}{8}$.
No. 2.	840	„ „ „	$40 \times 2\frac{3}{8}$.
No. 3.	1,229	„ „ „	40×2.
No. 4.	1,093	„ „ „	$40 \times 2\frac{1}{2}$.
No. 5.	1,348	„ „ „	$40 \times 2\frac{3}{8}$.
No. 6.	1,495	„ „ „	$40 \times 2\frac{1}{2}$.

These readings gave an average at each opening of 1,240 feet out during five minutes, or after correction of 1,390 feet, or 16,680 feet per hour. This amount calculated upon the net available area ($\frac{2}{3}$rds of a square foot at each opening) of the outlet openings gives the total amount of air extracted at a little above 11,000 cubic feet per patient per hour, or some 2,000 cubic feet per patient less than the amount passed into the wards. The channel by which this other 2,000 cubic feet per patient escaped from the wards we were not able to ascertain.

In order to test the sterilizing power of the furnace, two series of experiments were made similar in character to those employed at the Kendray Hospital, Barnsley. A hole in the chimney shaft immediately above the roof of the hospital was used for exposing capsules containing a thin layer of agar-gelatine to the action of the air after it had passed through the furnace. The method of preparation of these capsules and their contents was the same as that employed at Barnsley, with the exception that the capsules were enclosed in sterilized paper instead of in linen bags. At the time of the experiment the capsule was introduced within the chimney at the point above described. It was held by the experimenter (whose hands had previously been washed in a solution of corrosive sublimate) and pushed by him as far as possible into the chimney with the layer of the contained agar-gelatine held face downwards so that the current of air from the furnace impinged directly upon the agar-gelatine surface. After being allowed to remain in that position for a definite period, the capsule was withdrawn, re-covered, and returned to the sterilized paper.

The first series of experiments for testing the sterilizing apparatus were conducted on December 1st, 1891. In all, five capsules were employed. Three of these, namely, (*a*), (*b*), and (*c*), were exposed to the unheated exit air with the view of determining the condition of the air about to pass through the furnace. Thus :—(*a*) was exposed on the floor of the ward itself; (*b*) at the air outlet nearest the lavatory end of the ward; (*c*) in the vitiated air compartment close to the furnace. Of the remaining two capsules, one (*d*) was exposed, simultaneously with (*a*), (*b*), and (*c*), in the chimney above the lighted furnace in the manner already described. During a period of five minutes, ending one minute before these capsules were exposed, a door-mat was violently shaken in the ward in the vicinity of capsule (*a*). The fifth capsule (*e*), was exposed in the chimney above the furnace for a period of two minutes immediately after (*d*) had been withdrawn. From the date of exposure, December 1st, up to 10 a.m. on December 2nd, all five capsules were kept in the laboratory at the room temperature ; when, upon examination, over 30 pin-head colonies of moulds and bacteria were visible in (*a*), over 60 colonies in (*b*), and over 150 colonies in (*c*). In (*d*) and (*e*) no colonies were observed. The five capsules were transferred to the incubator at 11 a.m. on December 2nd and maintained at a temperature of 37 C. At 10 a.m. next day (December 3rd) many of the colonies in (*a*), (*b*), and (*c*) were found to have coalesced, and it was impossible to count them with any approach to accuracy. In (*d*) 27 and in (*e*) 10 pin-head colonies of moulds and bacteria were observed. Observations were then discontinued.

The second series of experiments for testing the sterilizing apparatus were conducted on February 23rd, 1892. Four capsules only were made use of. All were exposed simultaneously during a period of five minutes; (α) on the floor of the ward; (β) at one of the air outlets from the ward; (γ) in the vitiated-air chamber close to the lighted furnace; and (δ) in the chimney above the furnace. As on the previous occasion, a dusty mat was violently shaken in the ward one minute before the capsules were exposed. At 6 p.m. on the day of experiment the four capsules were placed in the incubator and kept at a temperature of 37° C. At 10 a.m. on February 25th a very large number of colonies of moulds and bacteria were found to have developed in capsules (α), (β), and (γ), many of which had coalesced and liquefied so as to render it impossible to count them. In (δ) there were no colonies; but it was then found that the heat from the furnace at the point of exposure had been so great as to dry the agar-gelatine to such an extent as to render it unsuitable for the growth of organisms. Observations were then discontinued.

As a control to both series of experiments, capsules containing agar-gelatine and prepared at the same time and in the same way as those used in the experiments, were kept under the conditions applying to the latter after exposure. In no case did any colony appear in any of these.

In all the hospitals hitherto referred to in this memorandum the action of heat is depended upon for extraction of the vitiated ward air along certain definite channels and for the subsequent sterilization of this air. At Barnsley and at Nottingham gas was employed for these purposes, but at both these places, as I have already noted, the process adopted failed to secure either of these results in a satisfactory manner. At Bradford, where the heat of a furnace was employed, it was found that whilst the process adopted failed to secure satisfactory results as regards the sterilization of the ward air, a considerable measure of success was obtained with respect to the withdrawal of the vitiated air along certain definite channels at the time of experiment when the working of the apparatus was under the careful control of the designers. It is, however, scarcely necessary to point out that quite apart from the question of sterilization it is essential to the success of any method of artificial ventilation that its action shall be uniform at all times by night as well as by day, and when, as at Bradford, the system is dependent upon the efficiency of a stoker, uniformity in this sense cannot be regarded as secured.

Subsequently to the observations noted above, my attention was directed to a system of mechanical ventilation recently adopted at the Victoria General Infirmary, Glasgow, which was stated to have given very satisfactory results. I accordingly, under the Board's instructions, visited Glasgow and inspected the method of ventilation adopted at the Victoria Infirmary in company with Mr. Key, the designer. To Mr. Key I am indebted for a description of the Victoria Infirmary and of the system of ventilation carried out there by him. This description I append to my memorandum, since the method would seem likely to lend itself to the purpose that has not yet been fully achieved in regard of the small-pox hospitals I have dealt with.

FRED. W. BARRY.

October 1893.

APPENDIX.

EXTRACTS from a REPORT upon the VENTILATING and HEATING, by MECHANICAL MEANS, of the VICTORIA INFIRMARY, GLASGOW, by WILLIAM KEY, Engineer, Glasgow.

* * * *

The Victoria Infirmary, Glasgow, was formally opened for patients on Friday, the 14th day of February 1890, by His Grace the Duke of Argyll.

The buildings comprise an administrative block, which is three storeys in height at the centre, and four storeys at the wings. The ward block, also three storeys in height, is erected to the south of the administrative section, and is connected with it by light airy corridors 9 feet wide. The wards are 70 feet in length by 26 feet in width, and have a clear floor space, there being no fireplace, stove, or hot pipes in any of them.

On entering the wards, one immediately notices the entire absence of cornicing and woodwork, the intersection of the walls and ceiling being rounded off, and the corners of the windows finished with beaded moulding flush with the plaster; this simple style of finishing is, however, relieved by the lower walls being covered to a height of five feet with cream-coloured enamel tiles; another notable feature is the absence of square corners, all corners being rounded for the purpose of preventing the deposition of dust and animal effluvia of a poisonous nature.

The portion of the building between the ward staircase and administrative block is two storeys in height; on the upper floor is the children's ward, and on the lower floor are the servants' rooms. At the entrance to each ward is the ward kitchen and nurses' rooms, while at the other end are the bath-rooms and lavatories, which are cut off, ventilated, and heated quite distinct from the wards.

Let me state now what I felt then, and have more fully recognised since to be the essential features of a successful installation of mechanical ventilation.

1. The propulsion of fresh air into a building at its base and not the extraction of foul air by way of the roof.

2. The filtration through a damp surface, thus washing or scrubbing the entering air, its perfect purification from fog, and its separation from the floating impurities common to the atmosphere of large towns.

3. The warming of the air before it reaches the rooms to be ventilated, and the maintenance in these rooms of an equable temperature in all weathers without aid from hot water pipes, stoves, or fireplaces within the rooms.

4. The supply of the best and most economical motive power, and fan for the propulsion of the air; and the provision of sufficient heating surface with effective air tempering appliances all regulated to the size of the building, and to the purposes it is intended to serve, with due regard to safety and economy in the cost of warming.

5. The diffusion of the fresh air in the rooms ventilated, and its final expulsion from them, as well as from the whole building in a way to prevent the depositions of dust particles and its accumulation over ceiling joists under the roof, or any possibility of down draughts or backward currents.

6. The renovation of the air in rooms constantly occupied, at least six times per hour, in a manner to occasion no draughts or other inconvenience to those breathing it.

It will be seen, therefore, that while capable—as I shall endeavour to show—of producing admirable results mechanical ventilation is not a system to be applied blindly, but on the contrary, that the form of its application must vary more or less with the architectural features and purposes to which the building will be applied.

I confine myself, however, to my experience of the Infirmary, and proceed now to illustrate and explain the manner in which I have endeavoured to carry out the principles that have just been stated.

The Infirmary contains 400,000 cubic feet of air space, and the air inlet, main air ducts, and air channels into the wards, rooms, and corridors, are designed to permit of the whole air of these apartments being renewed from five times per hour to nine times per hour, as it may be found desirable or necessary.

The cold fresh air is drawn by the air propellers down a capacious air inlet 16 feet by 4 feet lined with white enamel bricks and open to the sky. The mouth of this inlet is placed 10 feet above the level of the ground, to obviate the drawing into it during stormy and dry weather the dust that is constantly being stirred up nearer the surface.

To renew the air of the Infirmary six times per hour, *two million cubic feet of air* are required. This volume of air as it passes down the inlet is filtered and washed by passing through an air washing screen of cords, formed of horse-hair and hemp closely wound over a top rail of wood and under the bottom rail, forming a close screen 16 feet long by 12 feet high, or nearly 200 square feet of surface. There is a constant trickling of water down this screen by which it is kept wet, and the air, in filtering through it, has the dust and soot particles removed, and when once these have adhered to the wetted surfaces, no current of air at whatever velocity can ever remove them, and they are carried down to float off at the drain by the falling water.

An automatic flushing tank is fixed in a position whereby 20 gallons of water are instantaneously discharged over the surface of the screen every hour, to flush and remove any

accumulation of wetted dust, soot, or germs which may not be removed from the screen by the trickling water over its surface. This goes on automatically day and night, and even in the district, where the Infirmary is built near to the Queen's Park, the atmosphere of which is supposed to be the purest in the city, the amount of soot particles which are extracted by this screen is something wonderful; a piece of jute Hessian cloth placed in the air current in front of the screen became in six hours nearly as black as graphite.

One of the chief advantages of the washing screen has proved to be the facility by which it removes every vestige of fog. During the past winter there were many days of fog of very great density, yet within this building, so soon as this screen was passed, the air was beautifully clear and bright.

These screens are now always erected with double filtering surfaces, cords of cocoa-nut fibre, jute, Hessian, or other cloth are employed over which to pass the water, and the air thus purified is a great boon to the inmates.

I deprecate the employment of any *dry screen of cloth or cotton wool,* as being a positive source of danger, owing to the accumulation of dust and germs, which must, as the screen gets laden, fall off under the velocity of the incoming air, and be floated throughout the building.

After passing the wet screen *the air is warmed* by coming into contact with steam-heated coils erected on a wooden platform.

There are eight distinct coils in the air chambers on this platform, the steam to each coil being admitted by a gun metal wheel valve, and the attendant may turn on one or more of the coils, or admit only a thin stream of steam to each, and thus increase or modify the temperature of each coil at pleasure. The coils are clustered in a space 16 feet long by 9 feet high, and formed of the best hydraulic tubes $\frac{7}{8}$ inch bore.

During winter it frequently occurs that the mornings are bitterly cold with keen frost, and provision is made for warming the air accordingly, but by 11 or 12 o'clock the sun shines forth and the air becomes warm and pleasant, to be followed in an hour or two by the air again becoming intensely cold. To meet this emergency in all installations of my system, air tempering doors are now erected between the incoming washed air and the heating coils; there may be from three to six of these doors capable of closing in the whole of the heating coils, and so prevent the incoming air from coming into contact with them; and while this is so, there is also provided *a corresponding number of bye-pass doors,* which are opened under the coil platform so as to bye-pass the air which is prevented from passing through the heating coils by the upper doors being shut; in this way the attendant can keep the temperature uniform and make alterations as rapidly as they take place with the external air.

In opening one or more bye-pass doors, and closing those in front of the coils, the cold air which passes through mixes with the warmed air from the coils as it passes through the air-propeller, and is forced inwards at the desired temperature. This can be done at once without waiting for the coils to cool down after shutting off the steam, or withdrawing the furnace fire when hot water pipes are used to warm the incoming air, and a great advantage of this system of tempering is that it does not reduce the volume of air moving inwards.

After passing the air-tempering appliances, *two air propellers of the Blackman Company type* collect the air and propel it forward through the main air ducts leading to the administrative block and to the wards. The form of the blades of this propeller are well suited for forcing the air along close ducts and channels, and the fans have been running for two and a half years, for 23 to 24 hours daily: not the slightest hitch having occurred by their use to interrupt the air supply. This must be considered a very severe test of their efficiency and durability.

The gas engines employed were of the best possible type for ventilating purposes The late Professor Carnelly, of Aberdeen, had made tests, by which he found that Messrs. Crossley Brothers' "Otto" gas engine propelled, by the Blackman Fan, 23 per cent. more air per cubic foot of gas used than the other competing engine using the same fan.

Crossley's engines performed their work to the satisfaction and admiration of all who saw them, and the only time these engines were stopped was for half an hour daily. One engine was stopped at a time, so as to cool and thoroughly oil it, during which time the other engine performed the duty of propelling the whole air into the building. These engines required and received very little attention, and developed the power required on an exceedingly small consumption of gas, being equal to 2*d.* per million cubic feet of air propelled into the Infirmary: this was latterly reduced to 1·42*d.* per million cubic feet of air by the introduction of my gas engine exhaust box, which not only prevented the noise of the explosive discharge from the cylinder being heard, although the products of combustion were discharged into the atmosphere within a few feet of the engine, but these were purified also in passing through it The engines were relieved of the pressure on the exhaust side of the piston, which formerly was a necessary accompaniment to the discharging the gases along narrow tubes with the disagreeable noise we have been familiar with, and which is now preventible.

The warmed air is by this mechanism impelled along the main air ducts leading to the wards and administrative chambers, and is further heated, either for the wards or for the administrative block, by passing upwards through secondary heating coils placed at the base of the flues leading to the several apartments and corridors.

The air enters each ward by wide, shallow ducts, placed along the wall 5 feet above the floor, the incoming air is thus directed towards the ceiling and is diffused throughout the higher levels, moving steadily downward from ceiling to floor; while the air, which had previously filled the space of each ward and chamber, is forced outward. The warmth of the fresh incoming air is utilised, warming ceilings, walls, and window spaces before passing off at the outlets.

The air, forced out of each ward and room, passes away by openings placed at the floor level. These admit the exhaust air into ducts within the walls which lead up to the roof where exhaust air chambers are placed over the ceiling joists, into which the various flues discharge. The air thus collected is led by wooden ducts, or ducts framed with wood lath and plaster to the roof ventilator outlets. Formerly the air from buildings ventilated on the propulsion system was discharged into the space under the roof, where the dust was deposited over the ceiling joists, and allowed to collect there, as there was no means of cleaning the spaces out between the joists. The air found its way out by valve and louvred frames in the gables, or placed over ridge of roof. The air is led by my method direct to the roof outlet within these ducts, which are periodically cleaned out and washed.

The roof outlet is formed square by setting up corner posts, with louvre boards between them on each side, and roofed in. Within this outer frame are placed the valve frames, through which all the out-going air must pass. The valves are made the full width of the frame in one piece of cloth 6 inches deep. By these a free passage is at all times available for the air to escape. Even in tempestuous weather or, during a gale, the outward flow is never interrupted, for while the valves are closed on the side of the cupola exposed to the influence and the pressure of the wind, those on the lee side are under no such pressure, the air passing out uninterruptedly, at the same time the closed valves on the windward side prevent any air whatever being admitted on that side to check the outward current.

The bath-rooms are heated and ventilated separately, and the temperature can be raised to any degree the medical superintendent may desire, so that patients on leaving a warm-water bath will step into a warm-air bath; the towels also and the drapery of the establishment require no special heating appliances as the whole air of the building is kept at a uniform temperature.

By this system, so imperceptible is the movement of this vast volume of air through the wards, that, when a velocity has been given to it sufficient to renew the whole air in seven minutes, not the slightest draught is observable.

It is only when a lighted taper is placed in the outlet at the floor level that the pressure within the apartment is observable, and the force of the current is at once perceived, for the light is extinguished thereby.

This copious volume of air blown into each ward is such that it may be said none of the inmates will ever inspire air which has previously passed through his lungs or those of any of the other inmates.

Some of the advantages are :—

General satisfaction has been expressed at the condition of the air in the wards at all seasons of the year; even the weak and delicate patients, from whatever cause they may be suffering, enjoy the comfortable fresh airiness of the wards equally with the strong, robust, and healthy visitor or official.

There is positively an entire freedom from draughts, and windows are never opened; there are ten beds, each containing a patient, set within 18 inches of and right across ten of the outlets near the floor, without the patients being sensible of any movement of air and certainly no draught.

There is not the slightest pulsatory motion of the air.

There is felt a sensation of airiness without any perceptible movement.

The delivery of air throughout the building is unaccompanied by any sound whatever.

A perfectly equable temperature under the varying conditions of atmospheric changes is remarkably easy to maintain by day and night.

The whole air supply is received into the building by one inlet, thus ensuring that it comes from the desired quarter and uncontaminated, while the outgoing air passes off by several outlets.

The whole air is heated and tempered in a manner which does not interfere with the volume of the air supply.

The supply of air is not dependent on the condition or temperature of the atmosphere, or whether the wind blows or the air be still, the supply being maintained positively and of a known quantity.

The air of the building is under a slight compression, and a glass U pipe containing water, one end connected by a rubber tube to the outer atmosphere, the other end being open to the internal air, a pressure of $\frac{1}{20}$ to $\frac{1}{10}$ of an inch of water column is recorded.

There being no fireplaces, no coals require to be carried, no ashes removed, and little dusting required.

There is thereby a great saving of labour.

There is none of the noise which usually accompanies poking and renewing of fires, and the uneven temperature of a room, by fires newly filled, burning brightly, then burning low, is totally absent.

The wetted surfaces of the air filtering screen is a decided improvement over any dry cloth or cotton wool screens; these must be frequently renewed as they become foul; I consider that it is highly objectionable to pass air into any building through a dry screen in process of becoming foul, or filtered through any kind of dry floor matting, which must collect its millions on millions of germs, these certainly will be scattered by the incoming air throughout the chamber, especially whenever disturbed by the feet of those in the apartment, this dust with the accompanying germs will be kept floating in the air by the *upward* currents, and be productive of serious inconvenience to those who perforce must inhale them.

All chambers wherein many persons congregate should have the air supply passed downward from the upper levels near the ceiling to the floor, so that all dust produced by the movement of the feet on the floor and exhalations from their bodies may pass off downward and not mix with the air to be inhaled.

All fresh air should reach the nostrils from above, in place of from lower point upward, accompanied as it must be by these emanations and dust particles.

I deprecate the blowing in of fresh air into the whole basement of any building, and thus converting it into an immense air chamber, and that for several reasons. Among these I may mention that the air will never be of one uniform temperature, owing to the fact that it is not propelled immediately on leaving the heating apparatus into the special passages constructed to deliver it into the chamber or chambers over.

This is accounted for by the fact that the air while passing, after it is heated, through the entire basement, which is so large as compared with the inlets to the apartments, it must do so comparatively slowly, and come into contact with floors, outer walls, stone pillars, &c., all conducting the heat formerly given to it to the outer face of walls, to the pavement of floors, and thus to the soil underneath, and warm currents will here and there ascend, but irregularly, with cold currents intermittently, as the volume of air is drawn or propelled through the inlets to the chamber.

At the Victoria Infirmary, by the present arrangements, the three wards can simultaneously have the temperature of the air increased up to 70° or 75° Fahr., while the rest of the building may be kept at 58° or 60.°

In the same way the wards may be kept at 55° to 60°, while any other portion may have the temperature of the incoming air raised to 70°.

I have, however, designed the heating arrangements for the new wards now being erected, so that the female medical ward, the male medical ward, and the surgical ward can each have any temperature over 50° Fahr. maintained in either of them as may be desired and independently of the others.

In January 1890. on my taking observations of the volumes of air passing into the buildings, I found that 51,080 cubic feet of washed and warmed air was being propelled into the Infirmary buildings every minute.

This was a volume of 3,064,800 cubic feet every hour, or equal to a renewal of the air every seven minutes, or nine times per hour; at that time the walls and plaster work was being rapidly dried to allow of getting on with the painters' work.

In December 1890, when the air volumes for each apartment had been regulated, the medical superintendent, Dr. Mackintosh, made observations of the air volumes, and was accompanied by the engineer, among whose duties were those of attending to the ventilating apparatus and that for electric lighting of the establishment.

Two anemometers were kept running for two hours in each of the two ducts, when it was found that 2,000,000 cubic feet of air was being propelled into the Infirmary every hour, and at a cost for power by the Crossley's "Otto" gas engines of gas consumed, of three half-pence per 1,000,000 cubic feet of air propelled—the gas costing 2*s.* 6*d.* per 1,000 cubic feet.

This was verified by running one of the air meters for two hours in the fresh air inlet when there was found to be only a very slight discrepancy, the meter in the cold air inlet, registering 1,971,200 cubic feet per hour or a difference of 28,800 cubic feet less.

This volume of two millions was equivalent to renewing of the air of the apartments ventilated mechanically six times per hour.

* * * *

KENDRAY HOSPITAL,
BARNSLEY.

SMALL POX PAVILION.

Plan A.

NORTH ELEVATION.

Scale: 12 feet to one inch.

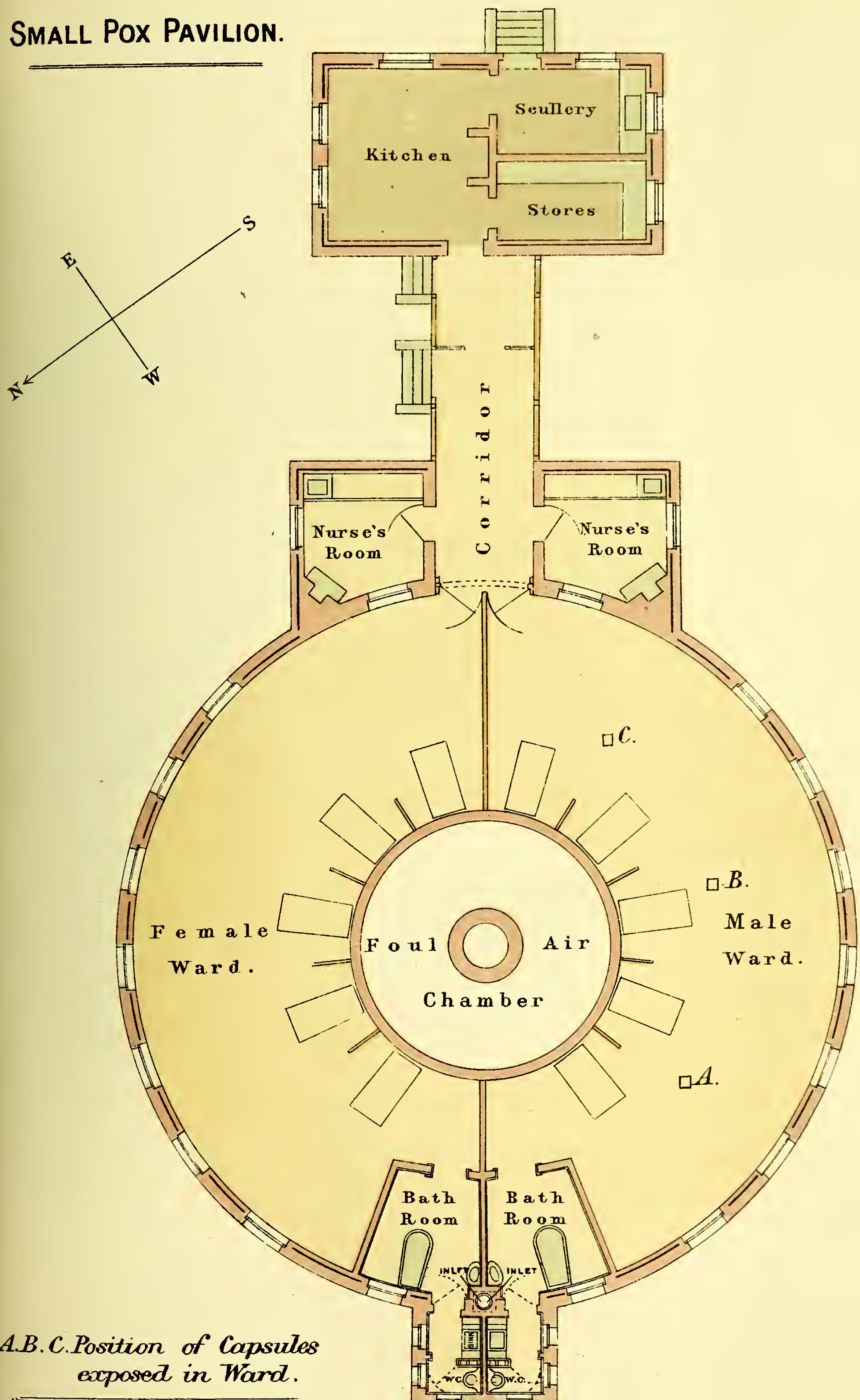
MORLEY & WOODHOUSE,
Architects,
BRADFORD.

JUDD AND Cº Lº LITH LONDON 4386.2.93

Kendray Hospital, Barnsley.

Plan B.

Small Pox Pavilion.



A.B.C. Position of Capsules exposed in Ward.

Ground Plan.

Scale:—12 feet to one inch.

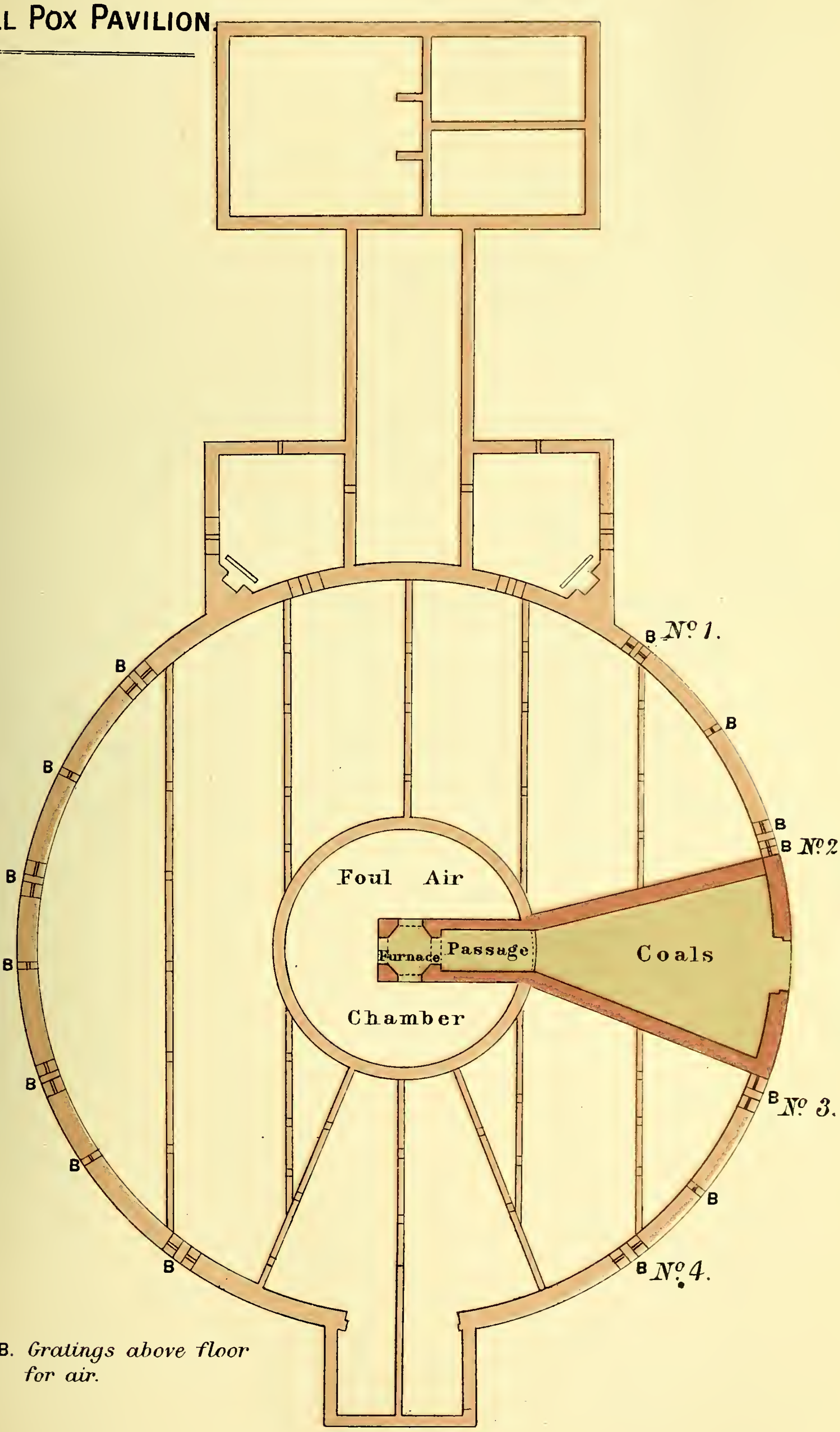
Morley & Woodhouse,
Architects,
Bradford.

Judd & Co Ltd. Lith 4386. 5. 98.

KENDRAY HOSPITAL,
BARNSLEY.

Plan C.

SMALL POX PAVILION.



B. *Gratings above floor for air.*

BASEMENT PLAN.

Scale:_12 feet to one inch.

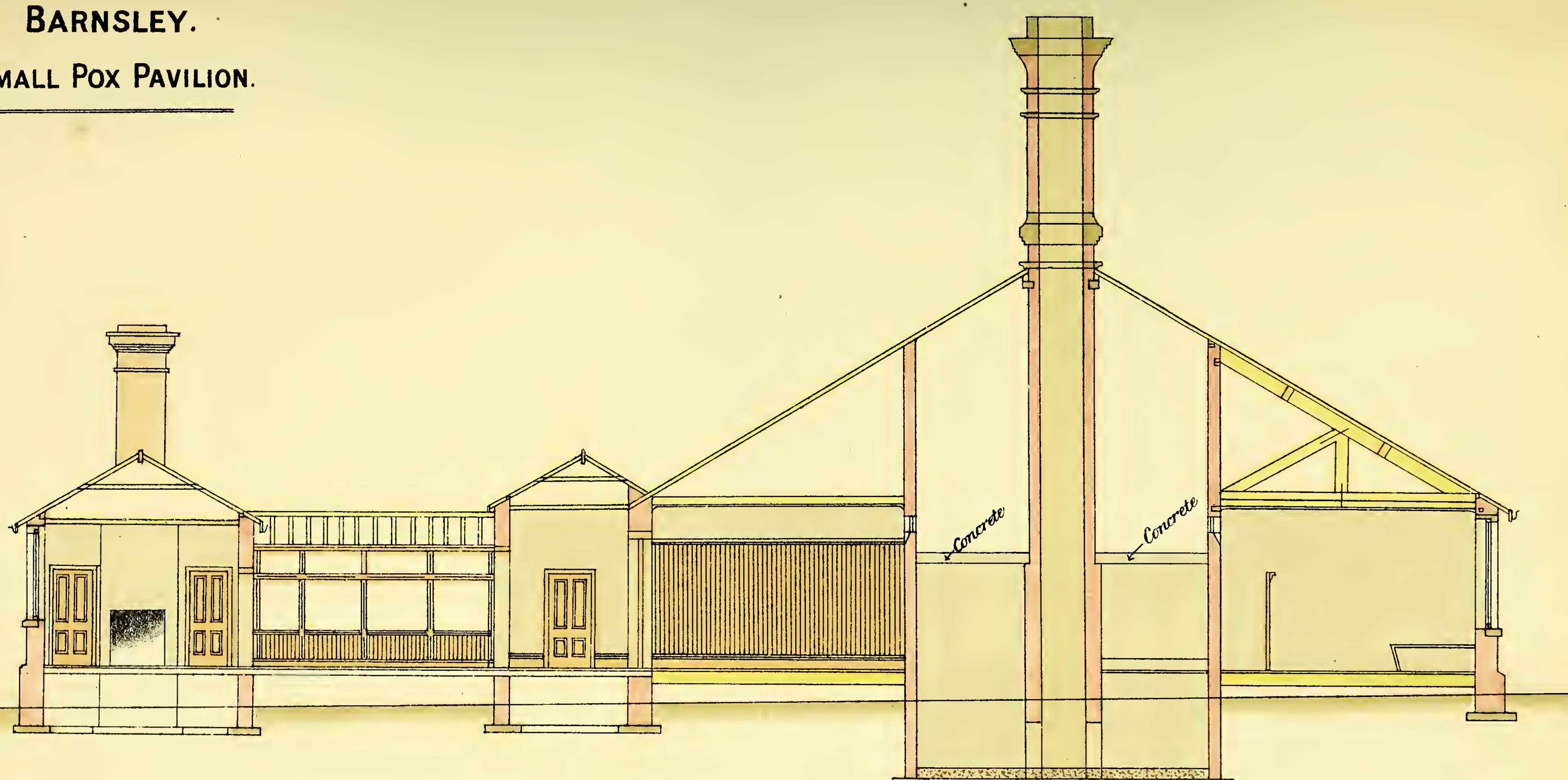
MORLEY & WOODHOUSE,
Architects,
BRADFORD.

Judd & Co Ltd, Lith 4386 .6.98.

Kendray Hospital,
Barnsley.

Small Pox Pavilion.

Plan D.



Longitudinal Section.

Scale: 12 feet to one inch.

Morley & Woodhouse,
Architects,
Bradford.

Judd and Co. Ltd. Lith. London 4386. 2. 83

KENDRAY HOSPITAL,
BARNSLEY.

SMALL POX PAVILION.

Plan E.

Scale: 12 feet to one inch.

TRANSVERSE SECTION.

MORLEY & WOODHOUSE,
Architects.
BRADFORD.

JUDD AND C° LTD LITH, LONDON 4386.2.93.

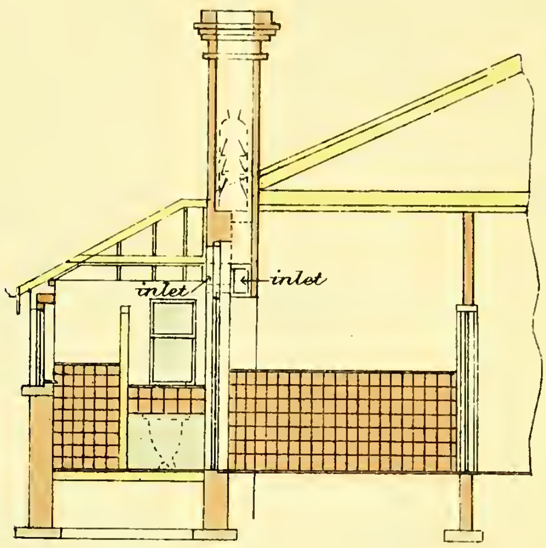
Kendray Hospital, Barnsley.

Small Pox Pavilion.

Plan G.

Section

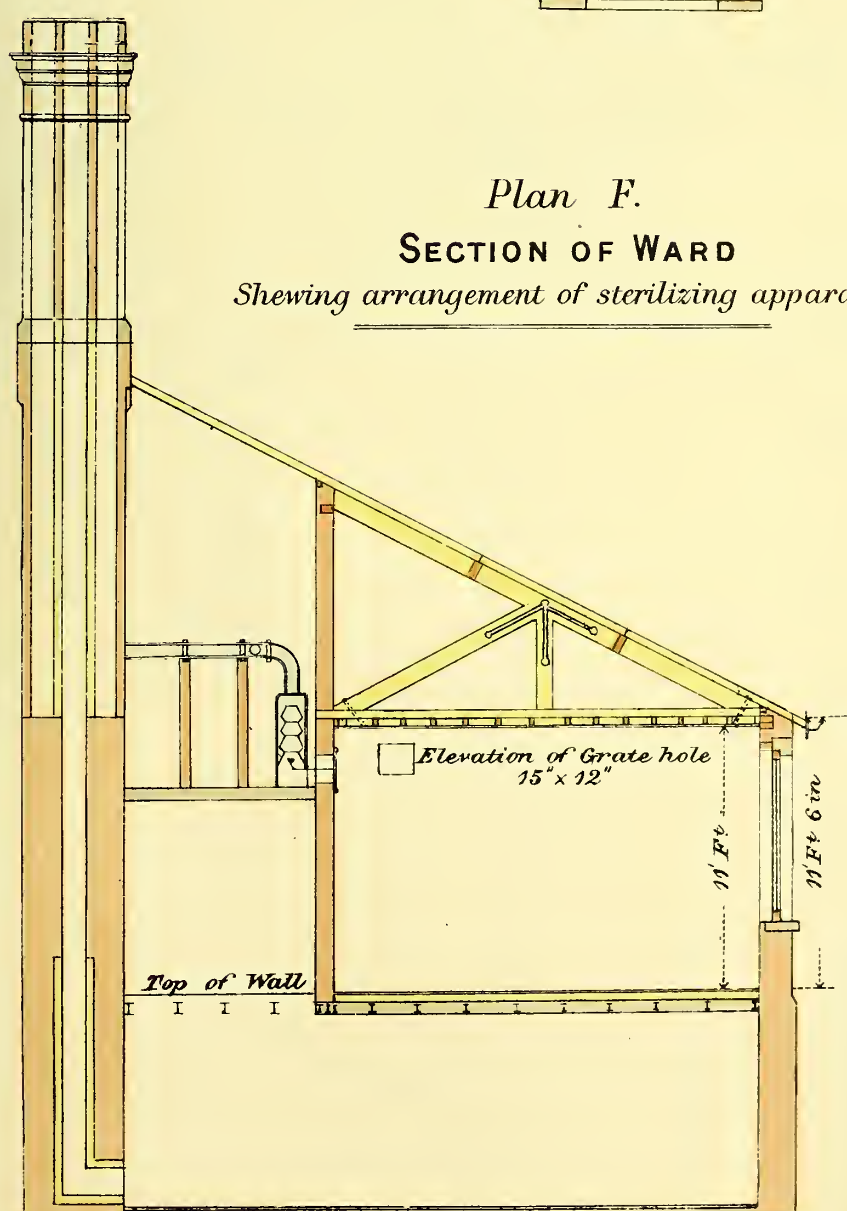
Shewing separate sterilizing arrangements made for water-closets and bath-rooms.



Plan F.

Section of Ward

Shewing arrangement of sterilizing apparatus.



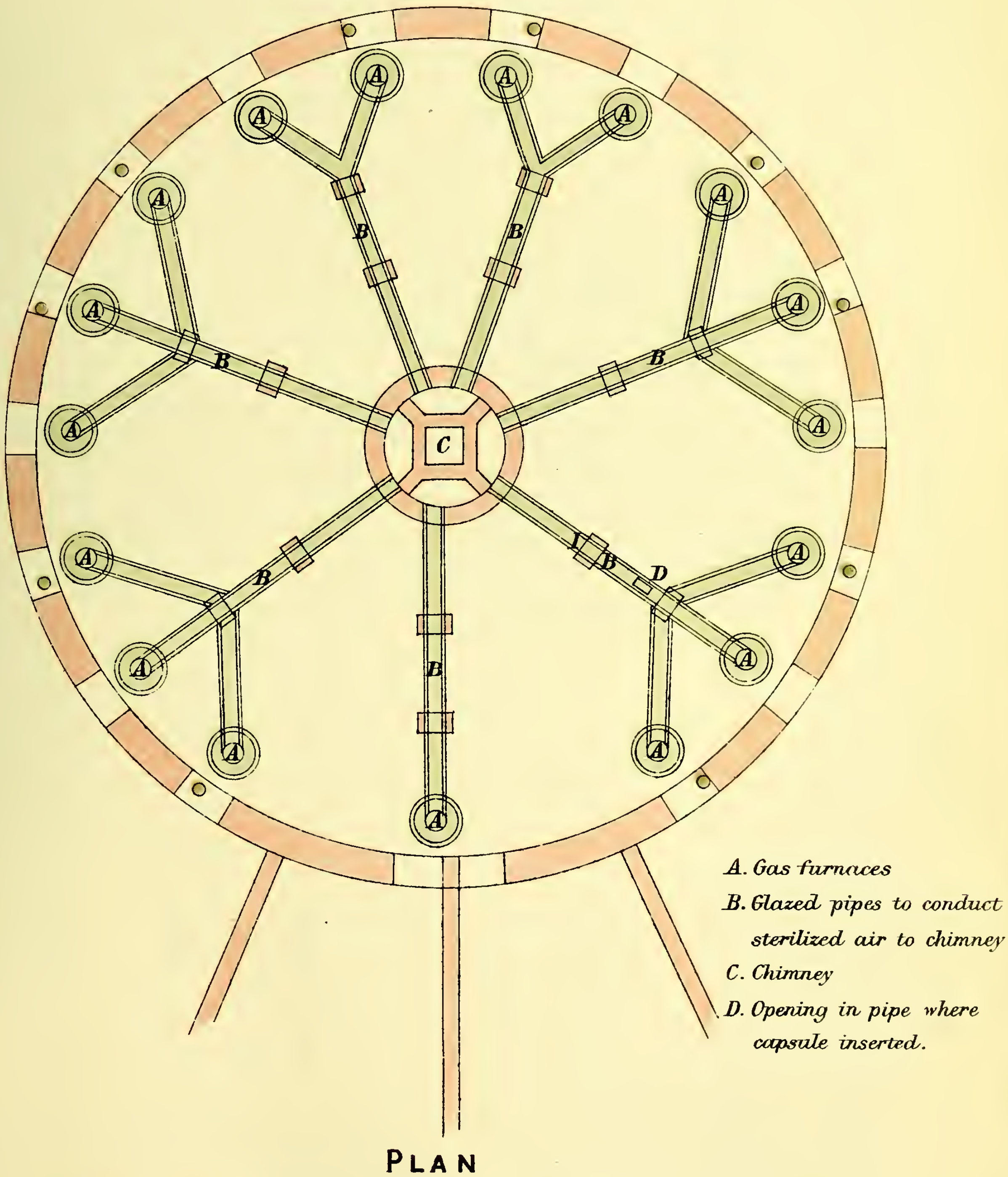
Scale: 8 feet to one inch.

Morley & Woodhouse,
Architects,
Bradford.

KENDRAY HOSPITAL,
BARNSLEY.

SMALL POX PAVILION.

Plan II.



PLAN

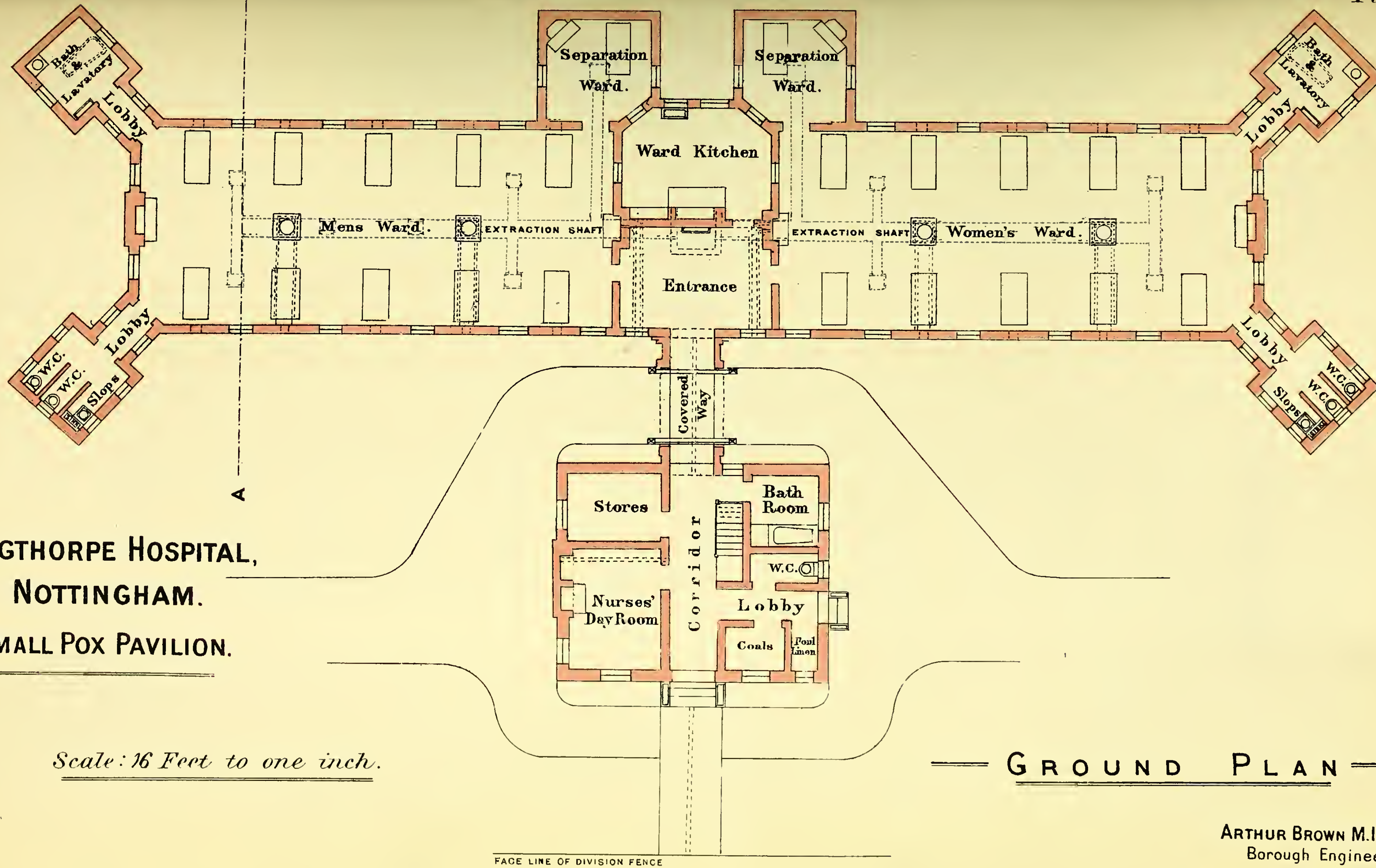
Shewing position of gas furnaces and air ducts in foul air chamber.

Scale: 4 feet to one inch.

MORLEY & WOODHOUSE,
Architects.
BRADFORD.

JUDD AND C° LTD LITH LONDON 4386. 2. 93

Plan I.



BAGTHORPE HOSPITAL, NOTTINGHAM.

SMALL POX PAVILION.

Scale: 16 Feet to one inch.

— GROUND PLAN —

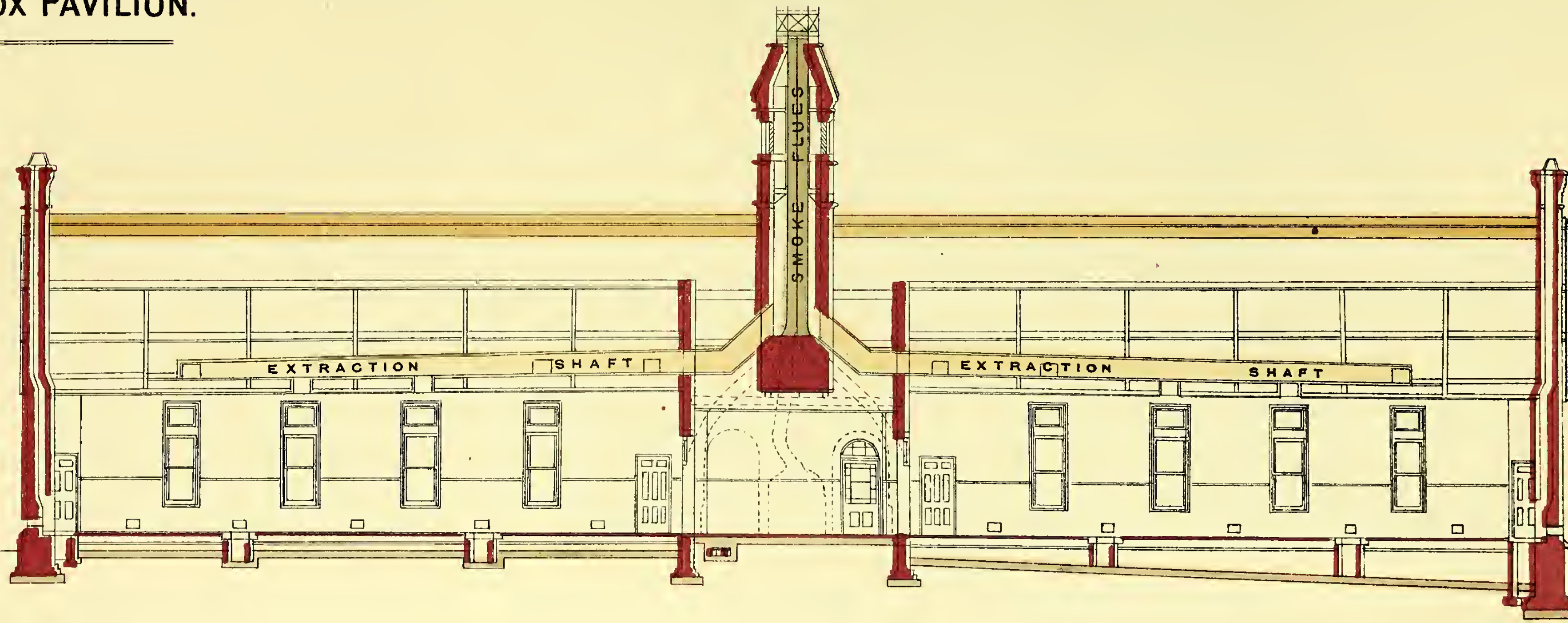
ARTHUR BROWN M. INST C.E.
Borough Engineer.
MARCH. 1892

Judd & Co Ltd, Lith. 63 Carter Lane, 4386. 5. 93.

Plan K.

Bagthorpe Hospital, Nottingham.

Small Pox Pavilion.



Longitudinal Section.

Scale:_16 feet to one inch.

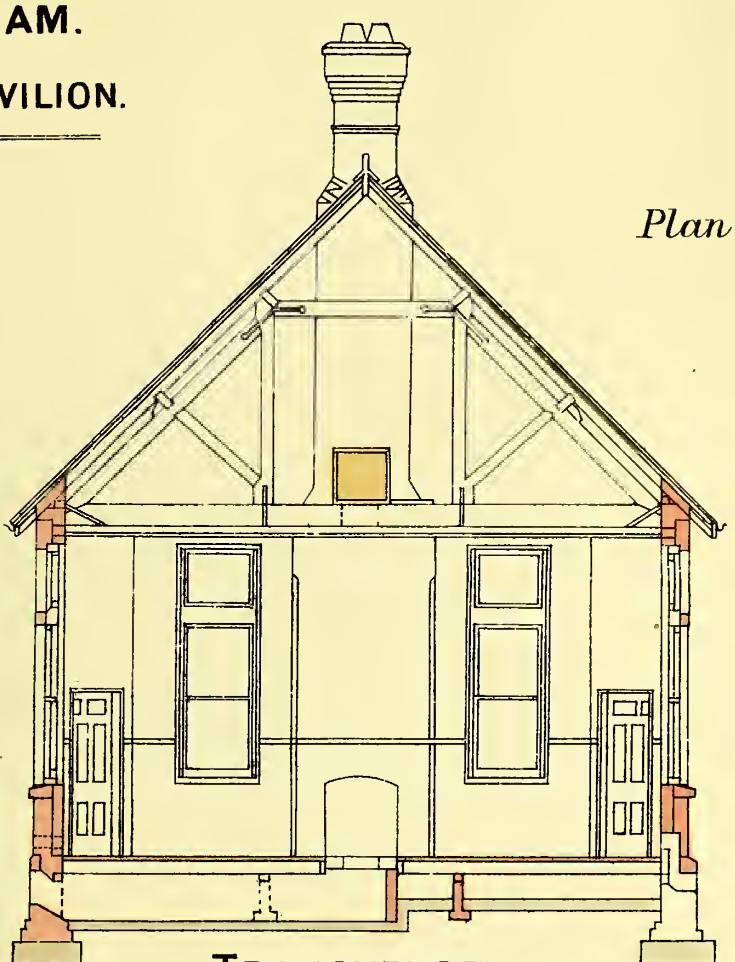
Arthur Brown M.Inst C.E.
Borough Engineer,
March, 1892.

Judd & Co Ltd. Lith 63 Carter Lane. 3346 5. 93.

Bagthorpe Hospital, Nottingham.

Small Pox Pavilion.

Plan L.

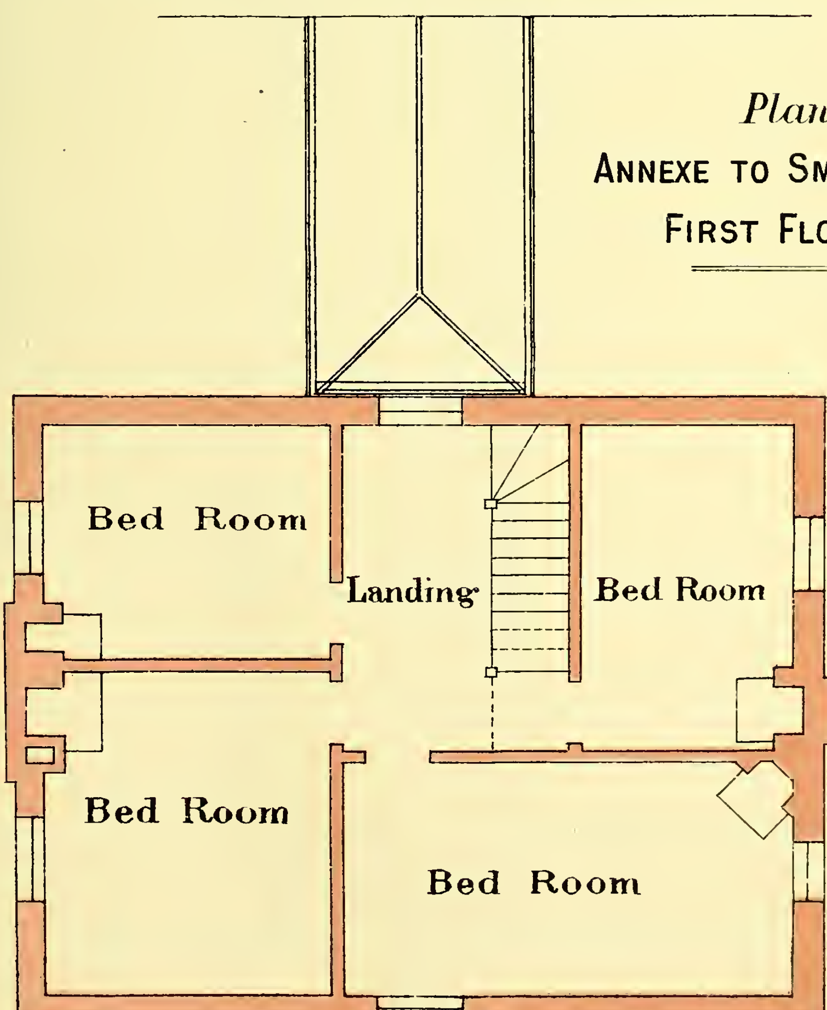


Transverse Section on line A.A.

Plan M.

Annexe to Small Pox Ward

First Floor Plan



Scale 18 feet to one inch

Arthur Brown M.Inst C.E.
Borough Engineer,
March. 1892

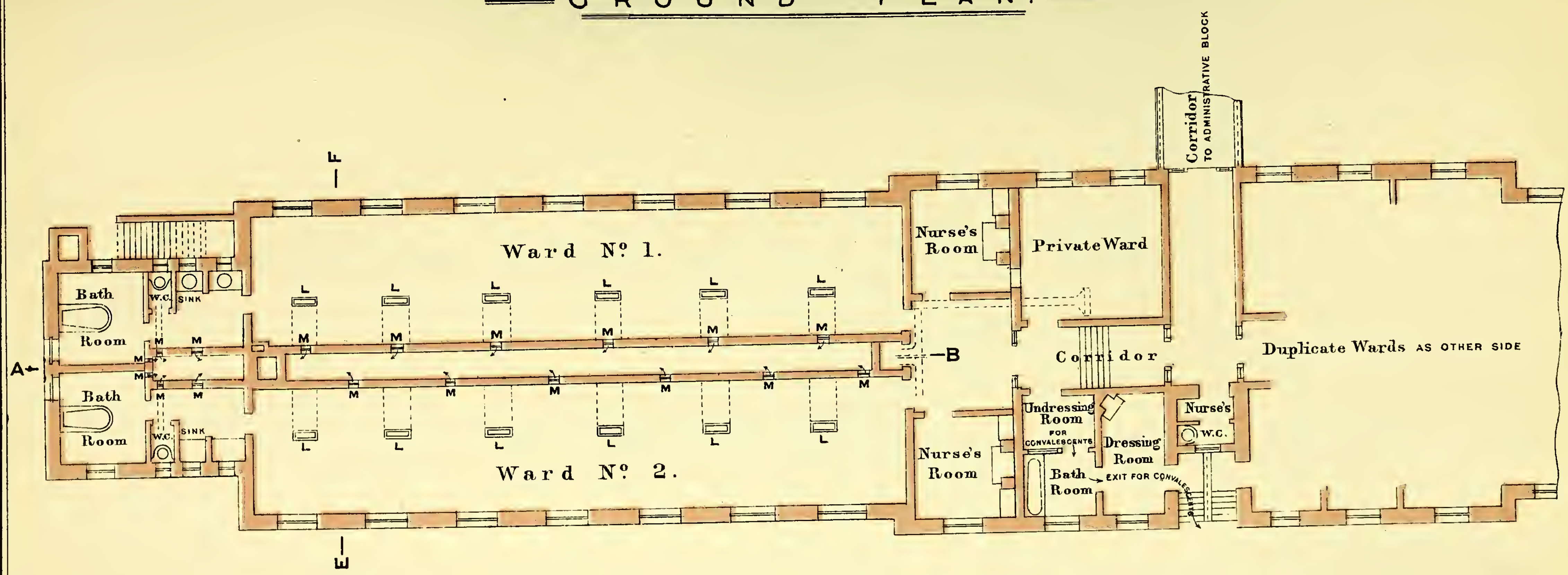
Judd & Co. Ltd. Lith. 63, Carter Lane. 4386.2.93

BRADFORD FEVER HOSPITAL,

SMALL POX PAVILION.

Plan N.

GROUND PLAN.



L. Gratings in floor for fresh air supply to Wards.
M. do. at ceiling level for extract of vitiated Air.

SCALE OF FEET.

10 5 0 10 20 30 40 50

MORLEY & WOODHOUSE,
Architects,
BRADFORD.

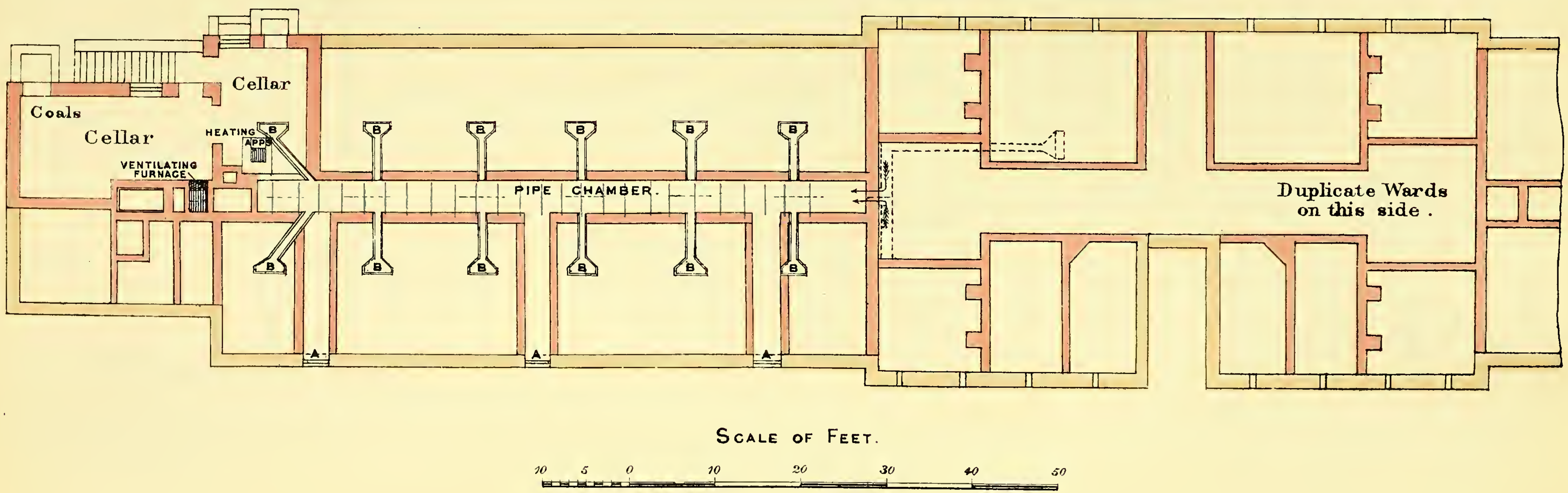
JUDD AND Cº Lᵀᴰ LITH 63 CARTER LANE 4386 5.93

Plan O.

Bradford Fever Hospital,

Small Pox Pavilion.

Basement Plan.



·A. *Cold air inlets*
B Fresh air flues thro' floor into Wards.

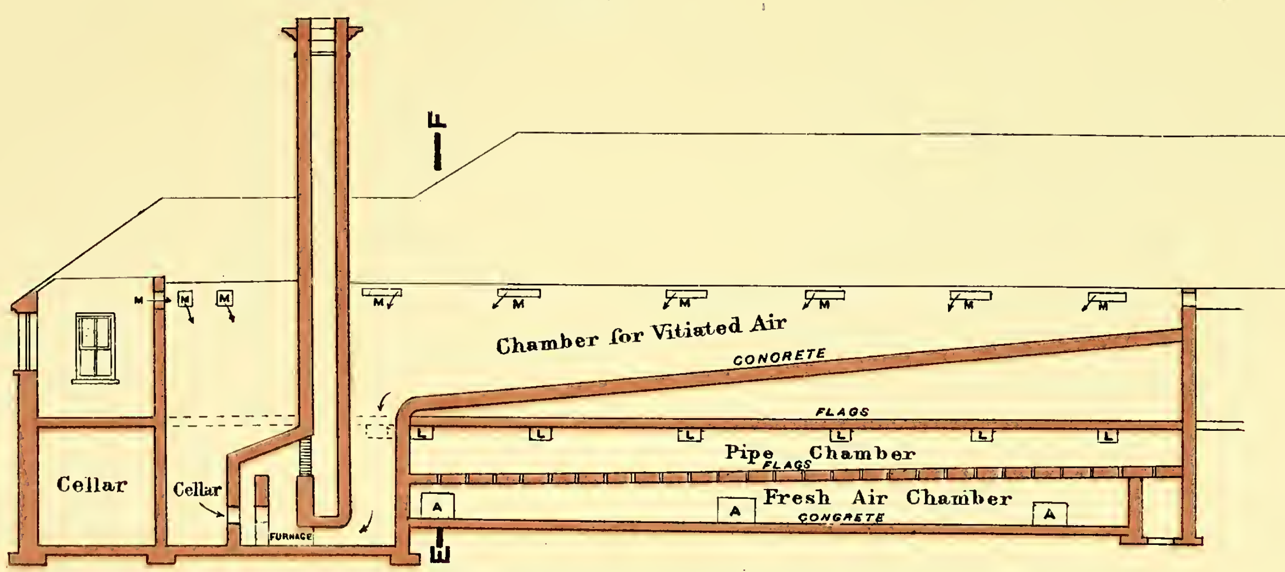
Morley & Woodhouse,
Architects,
Bradford

Judd & Co Ltd. Lith. 63, Carter Lane, 4386. 5. 93.

BRADFORD FEVER HOSPITAL,

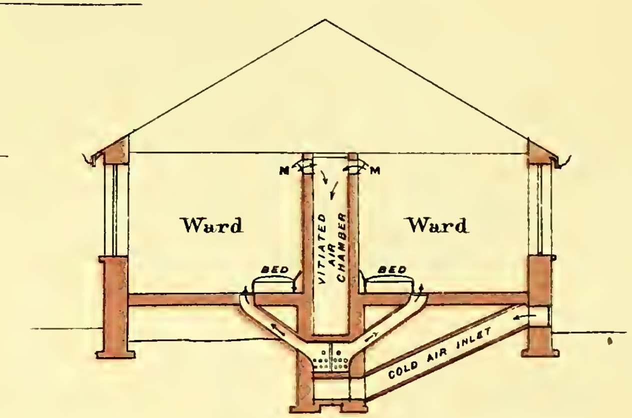
SMALL POX PAVILION.

Plan P.



SECTION ON LINE A.B.

Plan Q.



SECTION ON LINE E.F.

M *Gratings at ceiling level for extract of Vitiated Air*

A *Cold Air Inlets*

L *Fresh Air to Wards*

SCALE OF FEET.

10 5 0 10 20 30 40 50

MORLEY & WOODHOUSE,
Architects,
BRADFORD.

JUDD AND CO LTD LITH 63 CARTED LANE 4386-5/93

27. 2. 29
HmC.